Design options for radiation tolerant microstrip sensors for the CBM Silicon Tracking System (STS)*

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The expected neutron fluence for the CBM STS is 1×10^{14} $n_{eq}cm^{-2}$, after which an upgrade of sensors is foreseen. The main impact of radiation damage is the loss in the charge collection efficiency (CCE) limited by the breakdown voltage V_{bd}. Also we aim to minimize the capacitive noise. The dominant contributor to the capacitive noise comes from the interstrip capacitance C_{int}. To summarize, we aim to develop microstrip detectors having low C_{int}, high V_{bd} and maximum CCE.

Fluence Profile

Table 1 shows the expected neutron fluence for five years of required CBM runtime. In this table, the initial resistivity of silicon has been taken to be 5.33 KΩ-cm,the lifetimes of electrons τ_e and holes τ_h have been calculated using Kramberger's model [1] assuming an operating temperature of -10^{0}C. One can observe a deterioration of carrier life time with fluence which will have an impact on the CCE, especially on the p-side since this side collects less mobile holes.

Table 1: Fluence profile of neutrons for the CBM STS.

Year	Fluence (n_{eq} cm^{-2})	N_{eff} (cm^{-3})	τ_e (ns)	τ_h (ns)	V_{fd} (V)
1	2×10^{13}	2.8×10^{11}	1140	1050	28
2	4×10^{13}	-1.54×10^{11}	570	527	20
3	6×10^{13}	-5.35×10^{11}	380	351	44
4	8×10^{13}	-8.84×10^{11}	285	263	75
5	1×10^{14}	-12.1×10^{11}	228	211	100

Strip Isolation

In order to investigate the life time of sensors, it is imperative to extract the CCE as a function of fluence for which one has to understand the strip isolation in particular on the ohmic side. Hence various isolation techniques have been explored both through prototyping as also through simulations, for example P-stop, P-Spray, Modulated P-spray (conventional isolation techniques) and also a new isolation technique, the Schottky barrier. Schottky barrier can be defined either through metal work function value or through barrier height which in turn depends on the substrate type and the metal used for Schottky contact. For Aluminum, the barrier height is 0.72 eV for n-type silicon while for p-type silicon, the barrier height is 0.58 eV [2]. A comparison of the conventional isolation techniques with Schottky barrier in terms of V_{bd}, C_{int} and CCE is shown in Table 2. One can infer that the Schottky barrier is the best choice in terms of V_{bd} and C_{int}. However in terms of CCE, the Schottky barrier gives the worst performance especially after type-inversion. Therefore, Schottky barrier has not been opted as a suitable isolation technique. Besides P-stop and P-spray, another isolation technique namely modulated P-spray has also been explored. An optimization of modulated P-spray has been performed. It has been found that using a moderate P-stop width of around 15 μm and very low P-spray concentration of around 1×10^{15} $n_{eq}cm^{-3}$ gives the best performance in terms of V_{bd} and C_{int}, referred to as Optimized Modulated P-spray in Table 3. Finally a comparison of P-stop, P-spray and Optimized Modulated P-spray after one year of operation and the maximum fluence expected at the end of five years of CBM run is shown in Table 3. One can notice from this table that using Optimized Modulated P-spray, the V_{bd} has increased by around 60% and C_{int} has reduced by 25% while maintaining the same CCE as with conventional isolation techniques. In Tables 2 and 3, V_{bd}, C_{int} and CCE are simulated values confirmed with measurements. Hence Optimized Modulated P-spray is the best choice for isolation technique in terms of V_{bd}, C_{int} and CCE.

Table 2: Comparison of conventional isolation techniques with Schottky barrier.

Isolation Technique	Fluence (n_{eq} cm^{-2})	V_{bd} (V)	C_{int} (pF cm^{-1})	CCE %
P-stop	3.93×10^{12}	1010	2.1	91.25
	20.60×10^{12}	890	2.29	86.25
P-spray	3.93×10^{12}	524	2.6	93
	20.60×10^{12}	450	2.7	86.25
Schottky Barrier	3.93×10^{12}	1450	2.05	79
	20.60×10^{12}	1350	1.80	77.5

Table 3: Comparison between p-stop, p-spray and optimized modulated p-spray at low and high fluence.

Isolation Technique	Fluence (n_{eq} cm^{-2})	V_{bd} (V)	C_{int} (pF cm^{-1})	CCE %
P-stop	2×10^{13}	980	2.02	93.15
	1×10^{14}	720	2.03	88.87
P-spray	2×10^{13}	513	2.56	93.17
	1×10^{14}	495	2.44	89
Opt. Mod. P-spray	2×10^{13}	1600	1.58	93.22
	1×10^{14}	1150	1.60	89

References

[1] V.Cindro et. al., *IEEE Trans. Nucl. Sci.* N09-2, pp.139-142, 2006.

[2] http://www.pfk.ff.vu.It/lectures/funkc_dariniai/diod/schottky.htm.

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